# Optical Pumping DUT

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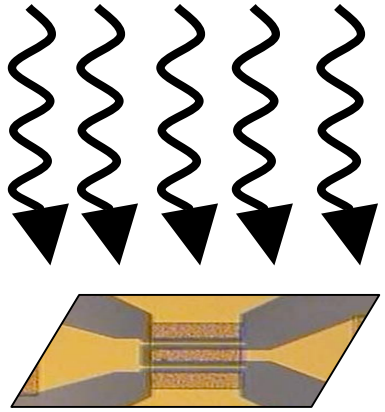
# Photo-pumping traps and DC measurement effects

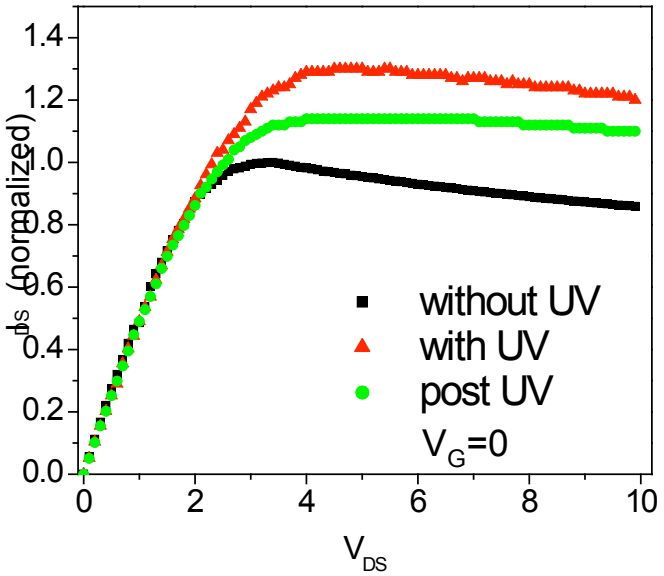
Hg arc lamp
Above $E_g$ energy photons



HEMT structure

30% increase in $I_{DS}$ with UV
17% increase in $I_{DS}$ post UV

Photons empty $e^-$ traps, cause the channel carrier conc. to increase.



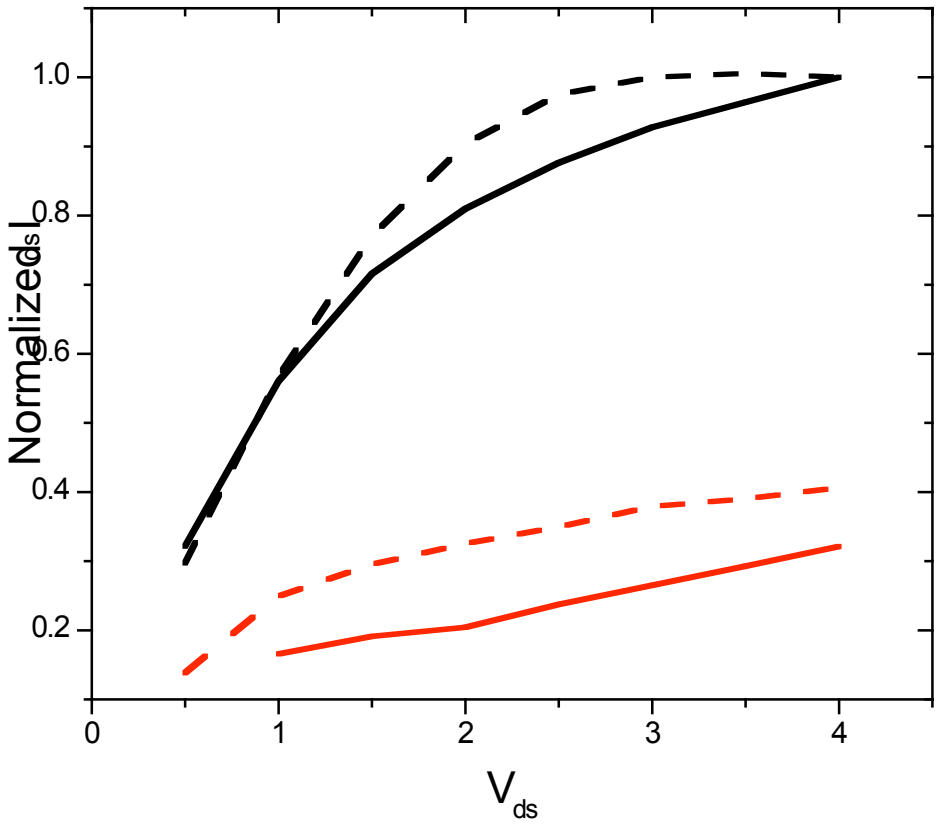

Difference of without UV and post UV is due to trap population

Pre-test $I_{DS}$ current level returns in ~3 days.

# UV Effects on $I_{DS}$ Current and Pulse Measurement

HEMT DC (as-rec)
HEMT pulse (as-rec)
HEMT DC (post UV)
HEMT pulse (post UV)

unpassivated HEMT



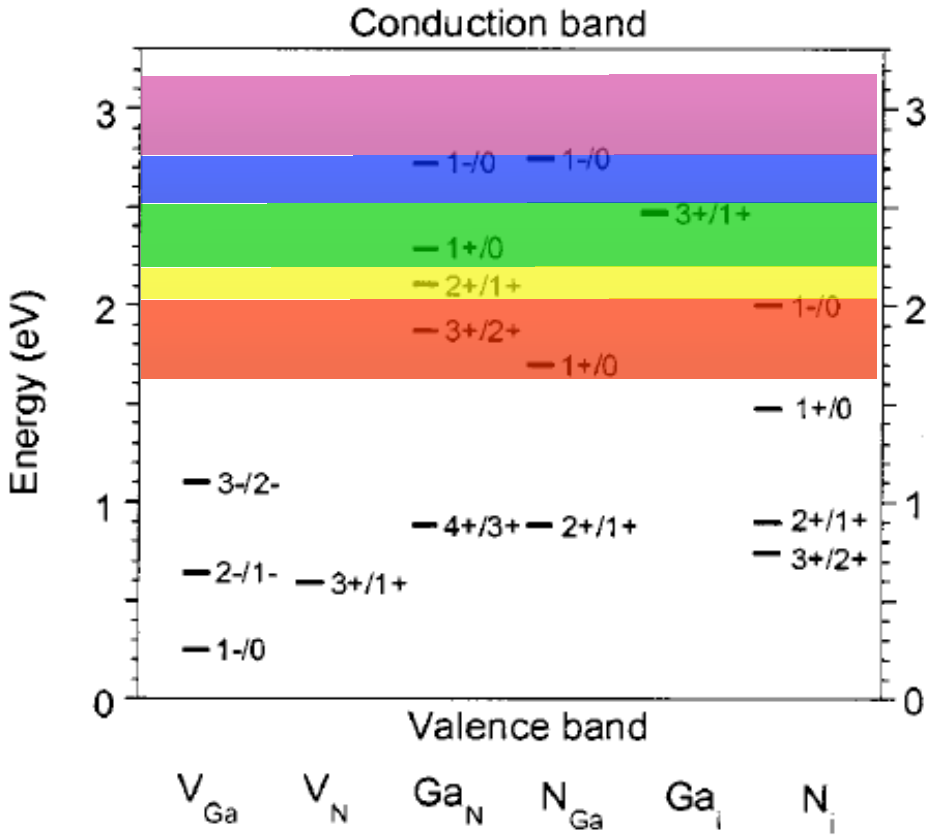

Rise in DC and gate pulsed $I_{DS}$ indicates traps (surface and/or bulk) are remaining emptied after UV illumination is removed.

Key is to add optical stress to the DUT to:
1) Determine type of trap associated with buffer and passivation failure
2) Accelerate aging by keeping traps empty (raise $I_{DS}$ without increase in $V_G$)

# Point Defects and energies within the GaN bandgap

Blue defect (center 2.9eV)
  $O_N$, dopants
Green defect (center 2.5eV)
  $V_{Ga}O_N$ , dopants
Yellow defect (center 2.2eV)
  several vacancy defect models,
  $V_{Ga}$ bound to dislocation, dopants
Red defect 660 (center 1.8eV)
  $V_NC_N$, implant damage, dopants

M.A. Reshchikov and H. Morkoc; JAP 97 (2005)

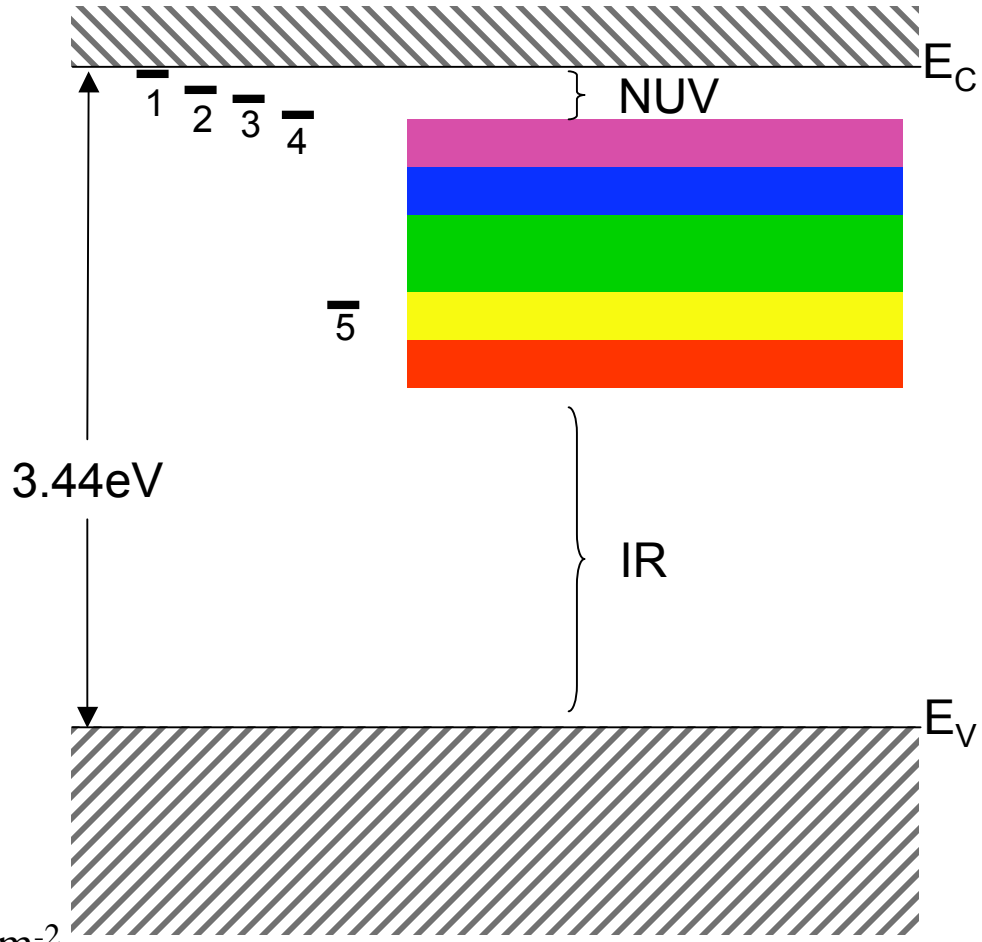



Transition levels for native defects in GaN, determined from formations energies.

Limpijumnong and Van de Walle; Phys. Rev. B 69 (2004)

# Defects and energies within the GaN bandgap

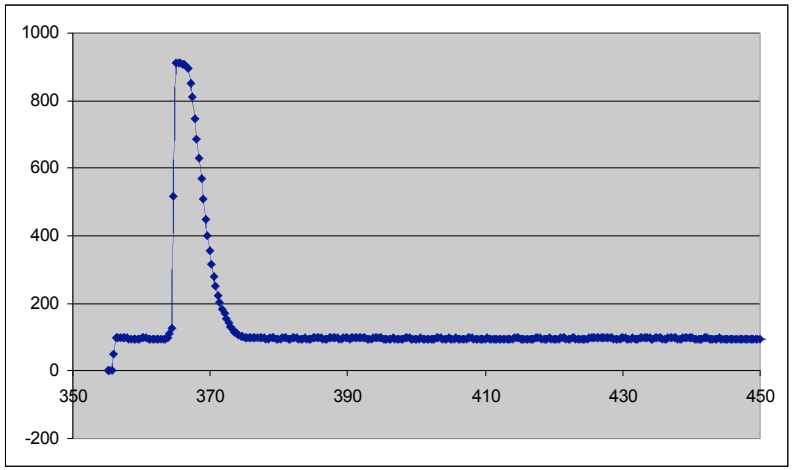
1. R. Lui et al; APL 86 (2005) –
   3.41eV BSF on polar GaN
   H.Z. Wu et al; APL 92 (2008) –
   3.41eV BSF on non-polar GaN
   M Albrecht et al.; APL 92 (2008) –
   a-type threading dislo.
2. R. Lui et al; APL 86 (2005) –
   3.34eV a-plane SF
3. R. Lui et al; APL 86 (2005) –
   3.28eV partial dislo.
4. C. Diaz-Guerra et al.; JAP 100 (2006) –
   3.20eV $C_N$
5. N. Yamamato et al; JAP 94(7) (2003) –
   2.21eV edge dislo. screw dislo. are invisible



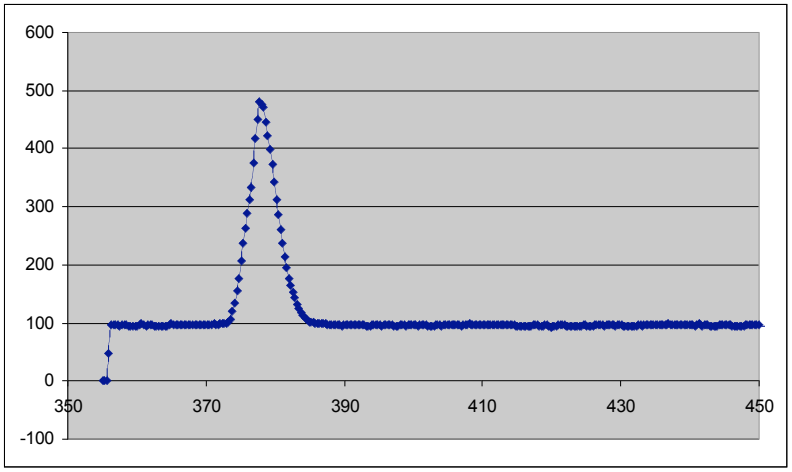

Dislocation densities typically $10^8$ to $10^{10}$ $cm^{-2}$

# Hg Arc lamp with monochromator (600 line grating)

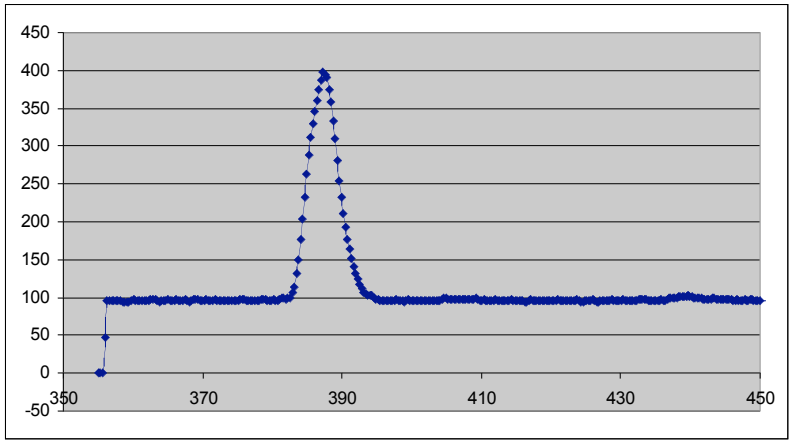
366nm = 3.39eV



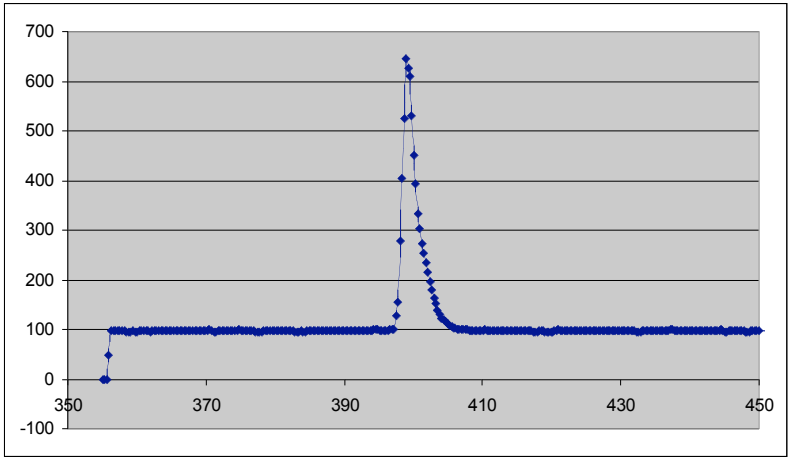

387nm = 3.20eV



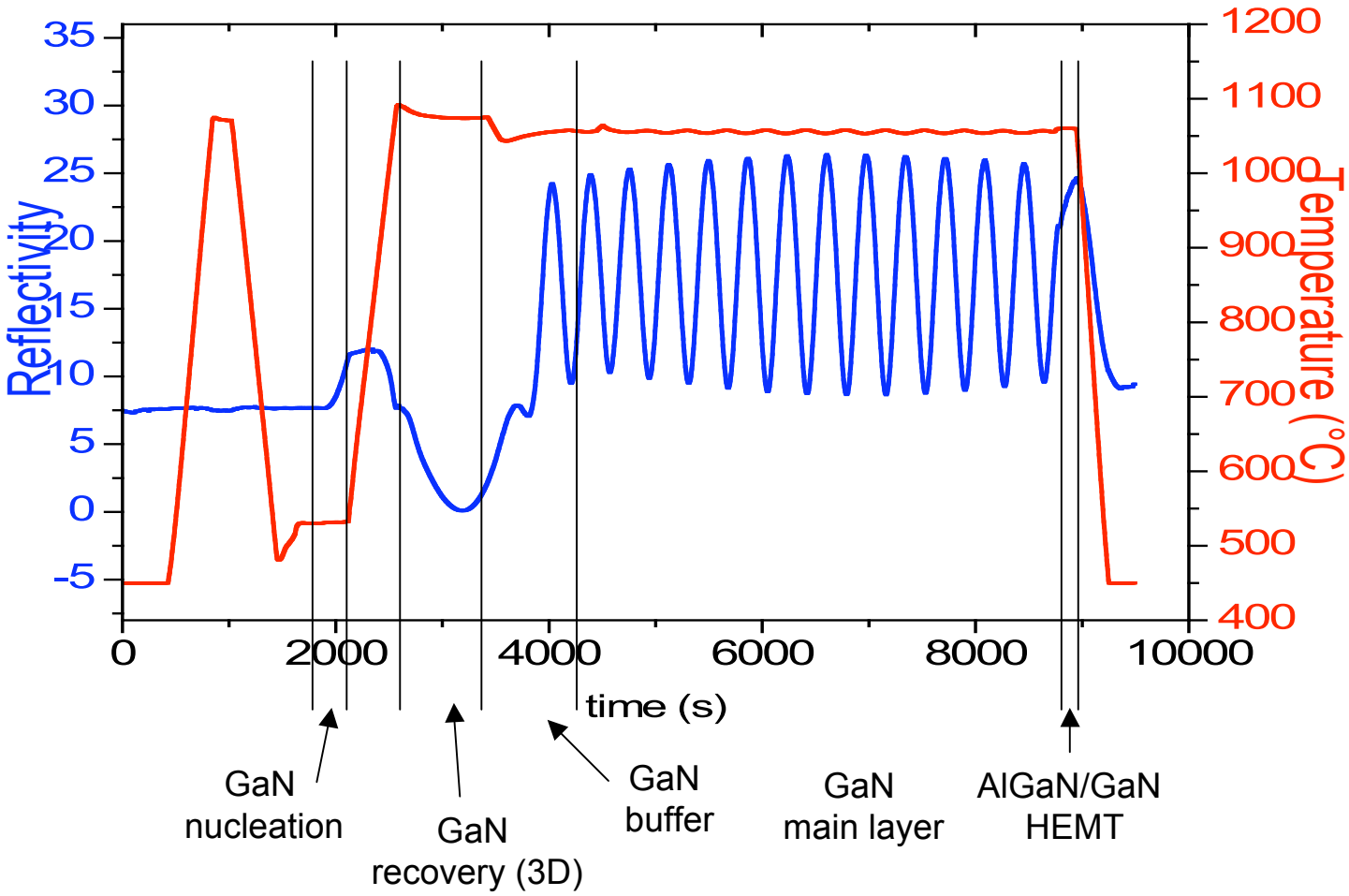

378nm = 3.28eV




398nm = 3.11eV



# MOCVD Growth of typical AlGaN/GaN HEMT

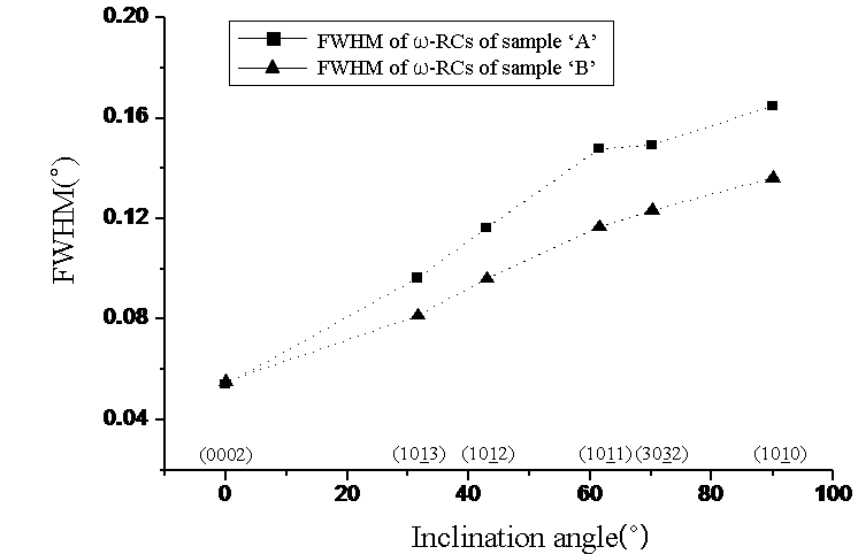


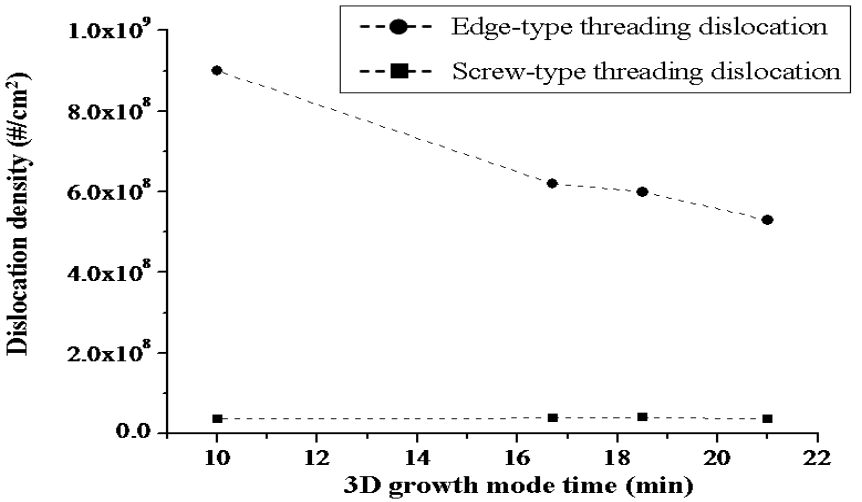
# Optimization of GaN 3D recovery layer

| Samples | 3D growth process | | | |
|---|---|---|---|---|
| | Temp. (℃) | TMGa (sccm) | V/III | $t_{3D}$ (min) |
| A | 1095 | 10 | 5964 | 10.0 |
| B | 1095 | 8 | 6088 | 16.7 |
| C | 1028 | 10 | 5964 | 18.5 |
| D | 1062 | 9 | 6012 | 21.0 |

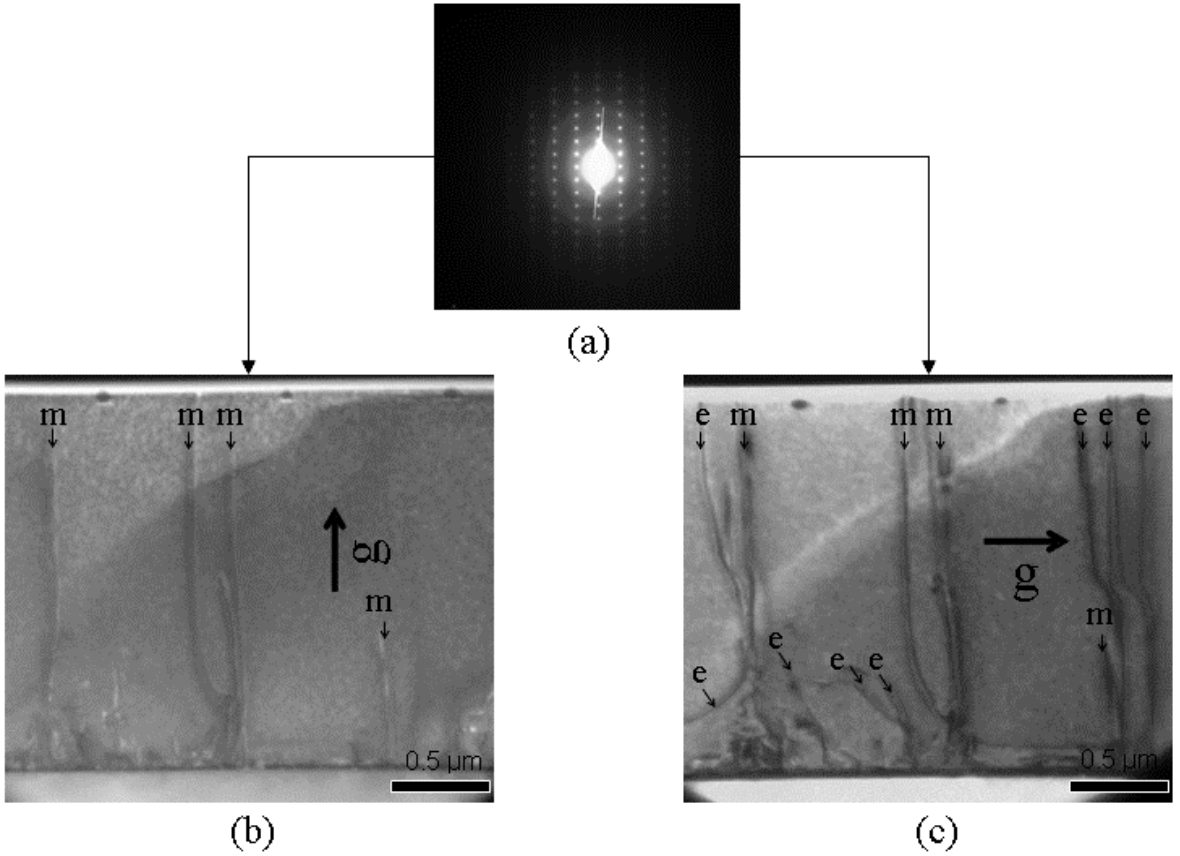
The dislocation density could be calculated by using FWHMs of the diffraction planes. The screw type dislocations are independent of the 3D HT island growth, while the edge type dislocations decrease with increasing 3D growth mode time.

J.H. Jang et al; JAP 103 (2008)



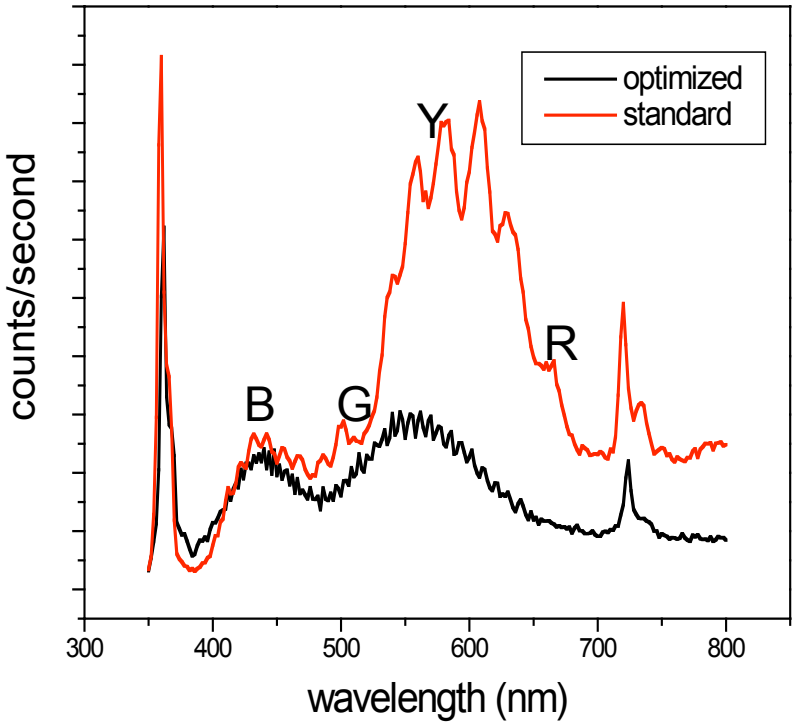



# Optimization of GaN 3D recovery layer

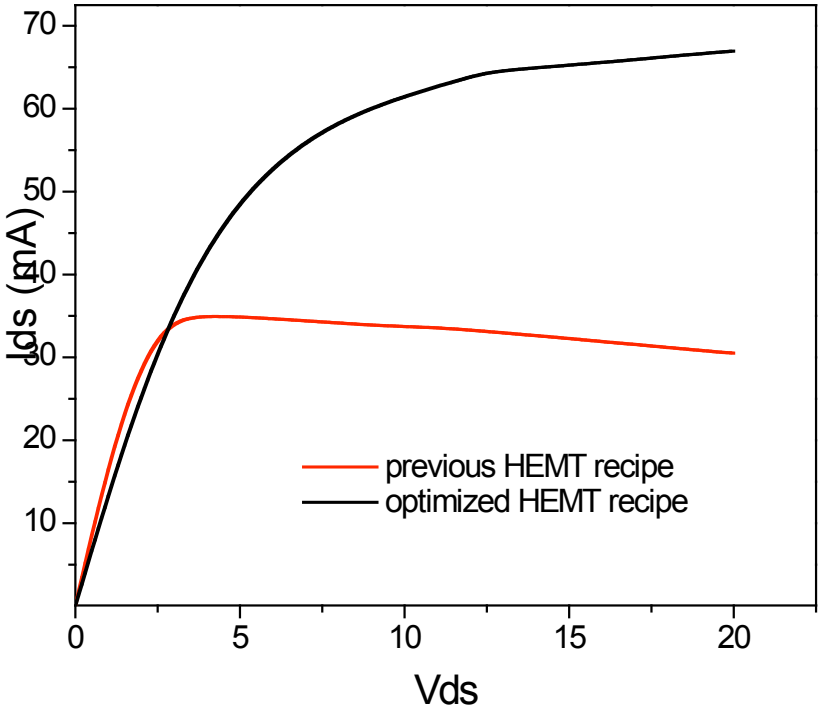



Cross sectional bright field images of sample taken near (a) zone axis using two-beam condition. The defects observed under (b) are screw or mixed type dislocations and ones under (c) are edge or mixed type dislocations. Sample D

# Optimization of GaN 3D recovery layer




Blue defect 440nm (2.82eV)
Green defect 520nm (2.38eV)
Yellow defect 560nm (2.21eV)
Red defect 660 (1.88eV)




Measuring a 4μm channel

Ids is almost 2x previous HEMT recipe

# How will optical stress enhance the program?

By optically pumping the DUT, an increase in accelerated aging will take place without adding stress to metal contacts or changing the electric field potential.

By discovering the traps and defects associated with poor device performance, limited lifetimes and current collapse, growth recipes can be optimized for more reliable device epi structures and processing recipes optimized for surface trap treatment.